The purpose of this study was to estimate the production of the *A. clausi* population and to assess its long-term changes for the summer seasons before (1957-1988) and after (1989-1996) *Mnemiopsis* invasion.

To achieve this, the following tasks were assessed:

- a mathematical description of the individual growth and development of marine copepods applied to experimental data which was obtained in laboratory conditions at a temperature range of 20-22 ^{0}C;
- an estimation of the daily production of the *A. clausi* population based on data of the Kamish Bay monitoring program carried out during 1960-1969;
- an estimation of the population production dependent on the number of late stages (copepodite IV and older).

2.Materials and Methods

2.1 Mathematical model description of the individual growth and development of *A. clausi*

Development of a model to describe the individual growth and development of *A. clausi*: In this model all parameters are different for naupliar and copepodite stages[7]. The experimental data on individual stage duration (d_i) and volumes, transferred to weights (W_i) with transition coefficient according to [8-10], were corrected according to Dayar and Prjibram (cited on [11]) equations:

$$W_i = a \cdot e^{\beta \cdot i} \quad \text{and} \quad d_i = d_0 \cdot e^{\alpha \cdot i}, \tag{1}$$

where i - stage of development, i=1,...,N; N=6 for naupliar stages and N=5 for copepodite stages; a, β, d_0, α - constants, and *e* - exponential function.

Then the continuous function $W(t)$ is established as:

$$W(t) = a \cdot q \cdot (1+t/\delta)^{\beta/\alpha} \tag{2}$$

where $\delta = d_0 / (1- e^{-\alpha})$ and coefficient q is found from the equation:

$$W_i = 1/d_i \cdot \int_{t_{i-1}}^{t_i} W(t)\,dt \tag{3}$$

Values of coefficients, included in the equations (1) were calculated by the method of least squares on data obtained from experiments in laboratory conditions at a temperature range of 20-22 °C [8, 10].

2.2 Method for the estimation of the *A. clausi* production

The individual daily increases in biomass were calculated as:

$$p_i = (W(t_i) - W(t_{i-1})) / d_i \tag{4}$$

The biomass and daily production of the *A. clausi* population in Kamish Bay during the summer seasons of 1960-1962 and 1964-1969 were calculated by the equation (5) - (5^1) as in the literature [12,13]:

$$P^1 = \sum n_i \cdot p_i, \quad \text{for } i = 2, \dots, 9. \tag{5}$$

$$B^1 = \sum n_i \cdot W_i, \quad \text{for } i = 2, \dots, 10 \tag{5^1}$$

Data on age-distributed numbers (n_i) were obtained by the Greze planktonometer [14] from the upper 40-meter layer. The index i and age group or stage correspond as given below:

i	1	2	3	4	5	6	7	8	9	10
group	egg	on	mn	c1	c2	c3	c4	c5	fem	male
	"young stages"						"older stages"			

The group *ortonauplii* (on) contains the first two naupliar stages and metanauplii (mn) comprise the others.

Due to the fact that most of the field data were obtained by a Juday net, which does not catch the youngest stages of copepoda [15, 16], the estimation of biomass and production was carried out with the older developmental stages (N_{7-10}). To account for this problem we suggest a linear regression as follows:

$Y = A + CX$., where $X = N_{7-10}$

For numerical estimation of the regression coefficients we have used the database of the Kamish Bay, monitoring program during 1960 -1962, 1964 - 1969 in summer. The data (N_{7-10}) were then multiplied by the catchability factor 1.87 [16].

The calculated formulae were applied to data on *A. clausi* numbers, from the zooplankton database which was created within the framework of the project " TU-BLACK SEA " for period 1957 -1996.

The spatial distribution of *A. clausi* stations is shown in Figure 1. The majority (88 out of 226) are in the north-western region of the Black Sea.

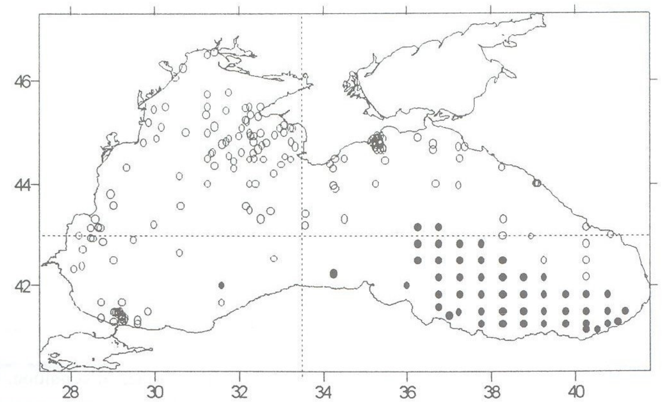

Figure 1. Distribution of *A.clausi* stations (o- IBSS, • - IMS) for the period 1957-1996.

3. Results and Discussion

A growth curve calculated according to equation (2), experimental and corrected values W_i are shown in Figure 1.

Average individual characteristics of *A. clausi* growth and development evaluated using equation (1) on experimental data [8] are shown in Tables 1 and 2.

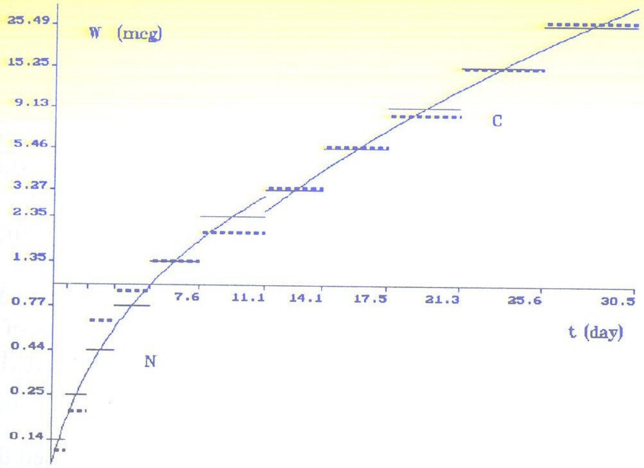

Figure 2. The individual growth curve $W(t)$ for *A.clausi* at temperature 20 - 22 °C on a logarithmic scale; N - for naupliar stages, C - for copepodite stages. Horizontal bars represent the average weights W_i of stages, broken lines for experimental and unbroken for corrected values.

TABLE 1. Average individual characteristics of *A. clausi* growth and development designed on the equations (1) and (3) applied to experimental data [8] for the temperature range 20-22°C.

N	Stage	Daily increase in biomass, mcg/day	Average ind. biomass, mcg	Duration of developmental stages, day
1	ova	-	0,309	0,50
2	on	0,0034	0,206	1,78
3	mn	0,291	1,468	9,29
4	c1	0,378	3,270	3,00
5	c2	0,824	5,464	3,39
6	c3	1,218	9,129	3,83
7	c4	1,803	15, 254	4,32
8	c5	2,668	25,488	4,88
9	f	3,950*	34,920	Σ= 30,49
10	m	-	29,920	-

*) Daily increase in individual adult biomass by generative growth was accounted at condition: interval between spawnings 1-1.5 days, size of spawning size 16 eggs ([9].

TABLE 2. Coefficients of equations (1) - (11), describing the individual growth of *A. clausi* at temperature range 20-22°C in experimental conditions [9[.

Stage of development	α	d_0	β	a	δ	q
Naupliar	0.3038	0.5590	0.5581	0.0826	2.1338	1.2868
Copepodite	0.1216	2.6564	0.5134	1.9570	23.1934	1.2720

Formulae for the estimation of *A. clausi* biomass (B^2 mg/m³) and production (P^2 mg/m3/day) on data for the number of older stages (N_{7-10}) from Kamish Bay are shown below.

$$B^2 = 0.031 \cdot N_{7-10} + 0.678 \quad (6)$$

$$P^2 = 3.02 \cdot N_{7-10} + 115, \quad (7)$$

The average production and biomass of the *A. clausi* population in different regions of the Black Sea for the period before the *Mnemiopsis* invasion and after are shown on Figure 3. The values of the *A. clausi* population daily coefficients P/B for these regions and periods are shown in Table 4. Both production and biomass of *Acartia* have decreased between 1.5 to 4 fold depending on the region. The maximal decrease took place in the north-western Black Sea. In the 1960's *A. clausi* comprised about 15 % of the total copepod biomass and production of the neritic zone [13]. However, in the period 1989-1996 *A. clausi* was seen to make up about 70 % of total biomass in inshore areas [5]. If we assume the same to be true with respect to production, we can conclude that the total copepod production has reduced by at least 10 fold. It should be stressed that these results are not applicable to any other season except summer, because of the essential differences in the population's age structures and in the production contributions of the various stages [17]. For example, in certain years explosive growth of the younger stages were observed. Such phenomena require a special interest and research. However the proposed approach may be applicable to other warm water species in the summer seasons.

TABLE 3. *A. clausi* biomass (mg/ m³) and production (μg / m ³ / day) in Kamish Bay estimated by different methods [12].

Year	Month	N_{7-10}	B^1	P^1	B^2	P^2	B^3	P^3
		ind/m3	eq. (5)	eq. (5`)	eq. (6)	eq. (7)	[17]	[12]
1960	7	458	14.71	1399	14.92	1498		
	8	121	5.21	608	4.44	480	8.7	1013
	9	61	2.17	225	2.58	299		
1961	7	242	8.68	935	8.20	846		
	8	219	7.66	756	7.49	776	5.7	1000
	9	75	2.77	307	3.01	342		

TABLE 3 (continued)

Year	Month	N_{7-10}	B^1	P^1	B^2	P^2	B^3	P^3
	7	158	7.26	841	8.60	592		
	8	164	4.38	471	5.57	610	6.1	850
	9	553	16.70	1625	17.88	1785		
1964	7	558	17.41	1811	18.03	1800		
	8	688	21.54	2238	22.07	2193	14.3	1669
	9	81	3.11	310	3.20	360		
1965	7	299	8.81	815	9.98	1018		
	8	300	13.62	1414	10.01	1021	9.6	1364
	9	334	10.83	1157	11.07	1124		
1966	7	123	4.26	431	4.50	487		
	8	130	4.28	474	4.72	508	3.2	335
	9	74	2.47	262	2.98	339		
1967	7	138	6.00	658	4.97	532		
	8	238	8.19	848	8.08	834	4.3	648
	9	29	1.30	153	1.58	203		
1968	7	197	6.50	705	6.80	710		
	8	616	17.95	1659	19.84	1976	7.5	1060
	9	29	1.11	117	1.58	203		
1969	7	1731	54.94	5356	54.51	5343		
	8	484	18.37	1920	15.73	1577	27.6	3715
	9	40	1.54	193	1.92	236		

A

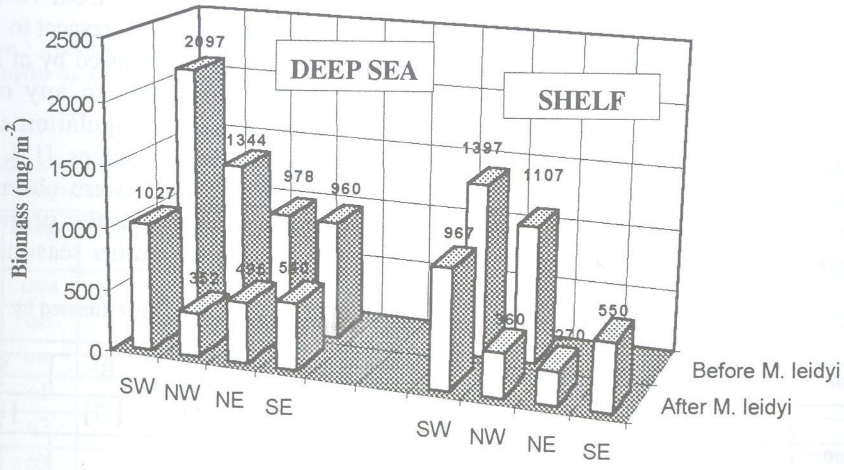

Figure 3.

B

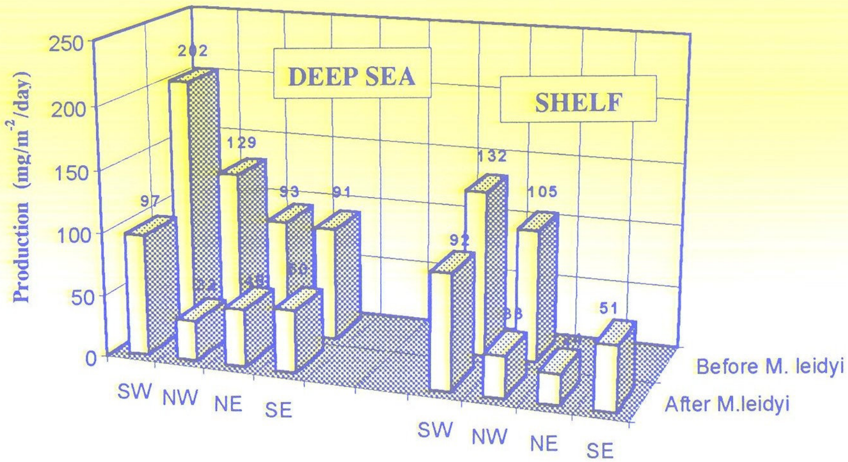

Figure 3. Biomass and production of *Acartia clausi* in the Black Sea before *Mnemiopsis* invasion (1957-1988) and after (1989-1996).

TABLE 4. Daily coefficients P/B of *A. clausi* in the Black Sea in summer before the *Mnemiopsis* outburst (1957-1988) and after (1989-1996). (n - total number of stations)

Region	Time	SW	n	NW	n	NE	n	SE	n
Deep	Before	0.096	5	0.096	10	0.095	4	0.095	1
	After	0.094	3	0.091	19	0.093	17	0.093	49
Shelf	Before	0.094	18	0.095	28	-	0	-	0
	After	0.095	7	0.092	32	0.089	30	0.093	3

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References.

1. Shushkina E.A., Vinogradov M.E. 1991. Long-term changes in the biomass of plankton in open areas of the Black Sea. Oceanology, 31:716-721 (in Russian).
2. Kovalev A.V., Ostrovskaya N.A., Skryabin V.A., Zagorodnyaya Yu.A. 1995. State of zooplankton, as a feed base of fishes in the Black Sea. In monogr. The modern state of Black Sea ichtyofauna. Sevastopol, IBSS:131-152 (in Russian).

3. Oven L.S., Giragosov V.E., Bagniukova T.V. 1995. Reproduction of some mass species of the Black Sea fishes under the antropogenic pollution conditions. In monogr. The modern state of Black Sea ichtyofauna. Sevastopol, IBSS: 39-74 (in Russian).
4. Gordina A.D., Klimova T.N. 1995. Dynamics of species structure and ichthyoplankton abundance in the coastal and open waters of the Black Sea. In monogr. The modern state of Black Sea ichthyofauna. Sevastopol, IBSS: 74-94 (in Russian).
5. Zagorodnaya Yu. A. 1995. Change of the size structure and productive indices of zooplankton. In monogr. The modern state of Black Sea ichtyofauna. Sevastopol, IBSS: 145-152 (in Russian).
6. Kovalev A.V., Zaika V.E., Sergeeva N.G., Ostrovskaya N.A., Melnikov V.V., Ivanova N.I., Tamoykin I.Ju. 1991. Distribution, ecological -physiological characteristics of ctenophora-invader in the Black Sea and connected with it changes of the plankton. 1991. Abstr. Of the paper sub. To the VI congr. All-Union Hydrobiol.soc.,8-11 October, 1991, Murmansk. Murmansk, Izdat. " Polarnaja Pravda ", 1: 137-138 (in Russian)..
7. Ostrovskaya N.A. , Pavlova E.V., Sazhina L.I. 1982. Quantitative characteristics of length and weight growth in Scolecithrix dana (Lubbock) from tropical zone of Indian Ocean. Ecologia morja, vip. 9, pp. 94-102.
8. Sazhina L.I. 1973. Growth of mass species of copepoda of the Black Sea in laboratory conditions. Biologia moria, vip. 28, pp. 41-51.
9. Sazhina L.I. 1987 Reproduction, growth, production of marine copepods. Kiev, Naukova Dumka, 156 p.
10. Petipa T.S. 1957. About average weight of basic zooplankton forms in the Black Sea. Proc. SBS, vip. IX, pp. 39-57.
11. Makarova N.P. 1974 Regularity of linear growth in crustacea. Hydrobiol. journ. v. 10, vip. 3, pp. 84-89.
12. Greze V.N. 1967. Production in of heterotrophic marine organisms. Questions biooceanography. Kiev. Naukova Dumka, pp. 121-127.
13. Greze V.N., Baldina E.P., Bileva O.K. 1968. Production of planktonic copepods in the neritic zone of the Black sea. Oceanology, 8: 1066-1070 (in Russian).
14. Greze V.N. 1962. Use of planktonometer in marine plankton investigations. Oceanology, 2: 305-310 (in Russian).
15. Greze V.N., Fedorina A.I., Chmyr V.D. 1973. Production of the main components of food base of planktivorous fishes in the Black Sea. Biologija morija, 28: 3-23 (in Russian)..
16. Greze V.N., Baldina E.P., Bileva O.K, Makarova N.P. 1975. Effectivity of plankton collecting devices and estimation of real number of elements of pelagical biocenosis. Hydrobiological journal, 11: 108-111 (in Russian).
17. Greze V.N., Baldina E.P., Bileva O.K. 1971. Dinamics of number and production of zooplankton basic components in neritic zone of the Black Sea. Biologija morija, 24: 12-49 (in Russian).